

§2. Improvement of ECH Transmission Line for CW Experiments

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In the 7th experimental campaign, 84GHz power at the MOU output of 120 kW was injected up to 756 s. Several transmission components had been overheated and damaged during this operation. The temperature rise of the transmission components also made the excess out gassing from the waveguide wall that had limited the pulse duration of the injection.

In order to reduce the temperature rise in the waveguide system, almost all the straight waveguides are covered with copper plates with a water cooling pipe. The comparison of the temperature rise in several parts of the waveguide transmission line before and after the enforcement of the cooling are shown in Fig. 1. Temperature rises of several components in the transmission line before enforcement the cooling at the MOU output power of 120 kW, 756 s are shown by dotted lines and those after the enforcement at higher power of 160 kW, 1910 s are shown by solid lines. After the enforcement of the cooling, temperature rise rates become small even though the increased power and furthermore, these rise shows saturation.

In the last 756 s operation, out gassing from the waveguide wall due to the temperature rise caused the pressure increase over the critical pressure level that is set to prevent arcing inside waveguide. To control the out gassing from waveguide wall, enforcement of the cooling system should be the main solution, but due to the huge surface area of the waveguide wall, it is also necessary to increase the pumping rate through the waveguide. Up to the last experimental campaign, the pumping section of the waveguide had been set near the both end of the transmission line. Since the gas conductance of the 1.25 inch waveguide is very low, the evacuation from both end of the transmission line is not enough even if one set high performance evacuation port. It is essential to set many but not so much high performance pumping ports along the transmission line in such circumstance. We have developed new evacuation port for the 1.25 inch waveguide. The principle of the evacuation section utilizes a small gap in the corrugated waveguide. In order to minimize the loss and leakage power at the gap but to keep enough evacuation efficiency, the gap length is designed to be 1 mm which causes microwave leakage less than 0.1 %. Estimated molecular flow conductivity at this gap is 0.0022 m³/s while that of smooth 1.25 inch waveguide of 1 meter is 0.00387 m³/s. Nine of this type of new pumping section are distributed along the 62 m waveguide system. The comparison of the pressure rise in several parts of the transmission line before and after these improvements are shown in Fig. 2. Although

the power level increased by 30 %, the equilibrium pressure reduced to 1.0×10^{-2} Pa and this pressure level attained after 1000 s. These are result of both enforcements of cooling and evacuation. It is also noted that equilibrium pressure level after long pulse operation decreased shot by shot. This indicates that the waveguide wall conditioning proceeded by the long pulse operation and the out gassing rate decreased shot by shot.

Another component damaged in the last experimental campaign is the DC break. This DC break with a small gap in the waveguide and vacuum sealed by a ceramic disk had been used. The leakage microwave have heated this disk locally and finally made a crack which lead the break in the vacuum. This ceramic is replaced by an aluminum disk with the same size but alumite coated for electric insulation.

These improvements had been the key to succeed more than one hour injection of the ECH power into LHD at the power level of 110 kW.

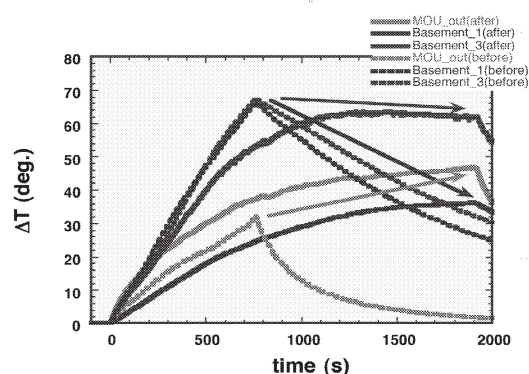


Fig. 1. Time evolution of temperature rise in the transmission components during long pulse operation before enforcing the cooling (dotted lines) and after (solid lines).

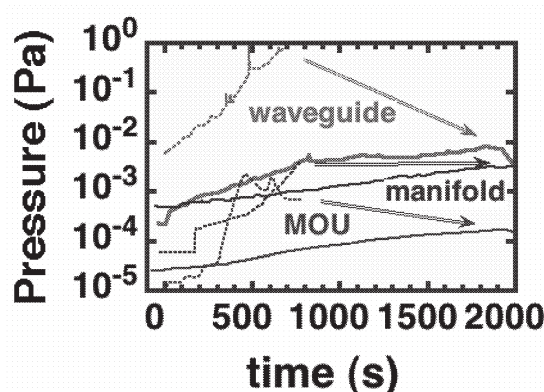


Fig. 2. b) Time evolution of the pressure in the transmission line at MOU, mid-way on the waveguide line, and evacuation manifold before (dotting lines) and after (solid lines) improvements.